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RESEARCH MEMORANDUM

for the

Civil Aeronautics Administration

MODEL DITCHING INVESTIGATION OF THE

BOEING 707 JET TRANSPORT

By William C. Thompson

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NATIONAL ADVISORY COMMITTEE
FOR AERONAUTICS
WASHINGTON

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SUMMARY

The ditching characteristics of the Boeing 707 jet transport were investigated in Langley tank no. 2. A dynamically similar model of the airplane was used to determine the probable ditching behavior in calm water and the best ditching procedure. Various conditions of damage, landing attitude, and speed were investigated. Data were obtained from visual observations, acceleration records, and motion pictures.

It was concluded that the airplane should be ditched at a nose-high attitude of about 12° with the landing flaps down. The airplane will probably trim down, then trim up and make a fairly smooth ditching run of about 470 feet. The maximum longitudinal deceleration and the maximum normal acceleration will each be about $5g$. Some of the engine nacelles will probably be torn away and the fuselage bottom will most likely be damaged enough to cause rapid flooding.

INTRODUCTION

A ditching investigation of a model of the Boeing 707 jet transport was made to observe the behavior and to determine the safest procedure for making an emergency water landing. The ditching characteristics of this airplane were of general interest as representative of the current trend in large swept-wing multiengine configurations with underslung wing nacelles or pods. (A three-view drawing of the airplane is shown in figure 1.) The investigation was made in calm water at the Langley tank no. 2 monorail.

APPARATUS AND PROCEDURE

Description of Model

The 0.043-scale model of the Boeing 707 jet transport shown in figure 2 was used in the investigation. The model was designed and built by Boeing Airplane Company. It was constructed of balsa wood and spruce, and was covered with silk. Internal ballast was used to obtain scale weight and moments of inertia. The model had a wing span of 5.59 feet and an overall length of 5.50 feet.

The landing flaps were installed so that they could be held in the down position at approximately scale strength. To accomplish this a calibrated string was fastened between each flap fitting and a corresponding wing fitting so that water loads within ± 10 percent of the ultimate design load (3,000 pound full-scale normal load applied near the trailing edge of a flap) would cause the string to break. When the scale-strength connections failed the flaps rotated to the retracted position.

The engine nacelles were installed at approximately scale strength, in a manner similar to that described for the landing flaps. Each nacelle strut had a parting line near the nacelle; the strut and the nacelle were connected with a calibrated string which failed within ± 10 percent of the ultimate drag load (40,000 pounds full scale). When the scale-strength connections failed the nacelles became detached from the model.

The model was constructed so that a portion of the fuselage bottom could be replaced with an approximately scale-strength section. The manufacturer estimated the full-scale ultimate strength of the fuselage bottom surface to be approximately 10 pounds per square inch. The scale-strength bottoms were constructed of cardboard bulkheads and balsa-wood stringers and were covered with aluminum foil. A bottom is shown installed on the model in figure 3. Scale-strength bottoms were used to indicate the location and extent of damage that might occur in a ditching.

Test Methods and Equipment

Tests were made using the Langley tank no. 2 monorail (fig. 4). The model was ditched by catapulting into the air to permit a free glide onto the water. The model left the launching carriage at scale speed and the desired landing attitude with the control surfaces set so that the attitude did not change appreciably in flight. The behavior was recorded by a motion-picture camera and from visual observations. Accelerations were recorded by a two-component time-history accelerometer installed in the forward portion of the passenger compartment. The accelerometer components had natural frequencies of 73 cycles per second and were damped

to about 65 percent of critical damping. The reading accuracy of the instrument was $\pm \frac{1}{4}$ g.

Test Conditions
(All values are full scale)

Weight.- A gross weight of 130,000 pounds was used for the investigation.

Moments of inertia.- The model was ballasted to approximate the following values of moments of inertia:

Roll, slug-feet ²	1,700,000
Pitch, slug-feet ²	2,000,000
Yaw, slug-feet ²	3,500,000

Center of gravity.- The center of gravity was located at 26 percent of the mean aerodynamic chord and 60.7 inches above the fuselage bottom surface.

Landing attitude.- Three landing attitudes were used in the investigation: 12° (near lift-curve stall angle), 9° (intermediate), and 6° (low). The attitudes were measured with respect to the fuselage reference line.

Flaps.- Tests were made with the landing flaps in the up and in the down 50° positions. The down flaps were attached at scale strength.

Landing speed.- The landing speeds as computed from lift curves furnished by the manufacturer are listed in table I. The model was airborne when launched and within ± 10 miles per hour of these speeds.

Landing gear.- All tests simulated ditchings with the landing gear retracted.

Fuselage condition.- The model was tested with the following fuselage conditions:

(a) No damage simulated, figure 2

(b) Scale strength fuselage bottom installed, figure 3

Engine installation.- Tests were made with the engines attached at scale strength.

RESULTS AND DISCUSSION

A summary of the results of the investigation is presented in table I. The notations used in the table are defined as follows:

Ran smoothly - the model made no apparent oscillation about any axis and gradually settled into the water as the forward velocity decreased.

Skipped - the model made an undulating motion about the transverse axis in which the model cleared the water completely.

Ran deeply - the model moved through the water partially submerged exhibiting a tendency to dive although the attitude did not change appreciably.

Trimmed down - the attitude of the model decreased shortly after contact with the water.

Trimmed up - the attitude of the model increased.

General

No simulated damage. - The undamaged model with the flaps up ran smoothly at the 12° and 9° attitudes, and skipped and ran deeply at the 6° attitude. The maximum longitudinal deceleration was about $2\frac{1}{2}g$ and the maximum normal acceleration was about $4g$ in landing runs of about 890 feet at the 12° attitude, and about 1,100 feet at the 9° and 6° attitudes.

Ditchings with the flaps down resulted in smooth runs at the three attitudes tested. The maximum longitudinal deceleration was about $2\frac{1}{2}g$ and the maximum normal acceleration was about $3\frac{1}{2}g$ in landing runs of about 640 feet at the 12° attitude, 850 feet at the 9° attitude, and 1,040 feet at the 6° attitude.

Scale-strength fuselage bottom. - When the model was ditched with scale-strength fuselage bottoms installed it trimmed down immediately after contact with the water, then trimmed up and ran smoothly for the remainder of the run. This behavior was characteristic for ditchings at all three landing attitudes tested with the flaps either up or down. The changes in attitude during typical ditchings with the flaps down are shown in figure 5. Also shown in figure 5 are typical time-history plots of normal acceleration and longitudinal deceleration. Figure 6 shows sequence photographs of a typical ditching run at the 12° landing attitude.

Effect of Damage

Considerable damage occurred during all ditchings with scale-strength fuselage bottoms installed. When damage occurred it caused the model to trim down shortly after contact, and the landing runs were shorter and the decelerations higher than when no damage was present. Typical damage to the scale-strength portion of the fuselage bottom is shown in figure 7. Ditchings at the 12° landing attitude for the condition with the flaps down resulted in less damage than for the other conditions tested.

Effect of Flaps

When the model was ditched at the various landing attitudes with the flaps down, the scale-strength flap connections failed shortly after the model contacted the water and the flaps rotated to the retracted position. There was no noticeable difference in general behavior when the model was ditched with the flaps up or down, although ditchings with the flaps up resulted in somewhat more damage to the fuselage bottom due to the higher speeds necessary for flaps-up landings. Ditchings with the flaps up generally resulted in higher maximum longitudinal decelerations and normal accelerations than with the flaps down.

Effect of Landing Attitudes and Speed

A decrease in the landing attitude and the accompanying increase in speed contributed to more damage and slightly higher maximum decelerations at most conditions. Therefore, the nose-high attitude of about 12° is considered best for a ditching.

Effect of Engine Installation

Ditchings with scale-strength engine nacelle strut attachments resulted in two or three nacelles being torn away most of the time. There was no appreciable difference in behavior whether the nacelles were torn away or not. However, in tests made with the engine nacelles removed, the runs were longer and smoother than when the nacelles were attached.

CONCLUSIONS

From the results of the calm-water ditching investigation of a 0.043-scale dynamic model of the Boeing 707 jet transport, the following conclusions were drawn:

1. The airplane should be ditched at a nose-high attitude of about 12° with the landing flaps down.
2. The airplane will probably make a ditching run of about 470 feet and the maximum longitudinal deceleration and the maximum normal acceleration will each be about 5g.
3. Some of the engine nacelles will probably be torn away and the fuselage bottom will most likely be damaged enough to cause rather rapid flooding.

Langley Aeronautical Laboratory,
National Advisory Committee for Aeronautics,
Langley Field, Va., October 27, 1955.

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Approved:

John B. Parkinson

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mfd

TABLE I
SUMMARY OF RESULTS OF DITCHING INVESTIGATION OF A 0.043-SCALE
MODEL OF THE BOEING 707 JET TRANSPORT

[Gross weight, 130,000 lb; static normal accelerometer reading, 1g;
all values are full-scale]

Landing attitude, deg	Flap setting, deg	Landing speed, knots	Maximum longitudinal deceleration, g	Maximum normal acceleration, g	Length of landing run, ft	Motions of model
Undamaged model with scale-strength nacelle struts						
12	50	100	2	$3\frac{1}{2}$	640	Ran smoothly
12	0	119	$1\frac{1}{2}$	$3\frac{1}{2}$	890	Ran smoothly
9	50	104	$1\frac{1}{2}$	$3\frac{1}{2}$	850	Ran smoothly
9	0	127	$2\frac{1}{2}$	$3\frac{1}{2}$	1,090	Ran smoothly
6	50	113	$2\frac{1}{2}$	3	1,040	Ran smoothly
6	0	146	$2\frac{1}{2}$	4	1,100	Skipped, ran deeply
Model with scale-strength fuselage bottom and scale-strength nacelle struts						
12	50	100	5	$4\frac{1}{2}$	470	Trimmed down, trimmed up, ran smoothly
12	0	119	$6\frac{1}{2}$	$5\frac{1}{2}$	480	Trimmed down, trimmed up, ran smoothly
9	50	104	5	5	420	Trimmed down, trimmed up, ran smoothly
9	0	127	$5\frac{1}{2}$	6	500	Trimmed down, trimmed up, ran smoothly
6	50	113	6	6	450	Trimmed down, trimmed up, ran smoothly
6	0	146	$6\frac{1}{2}$	$5\frac{1}{2}$	700	Trimmed down, ran deeply

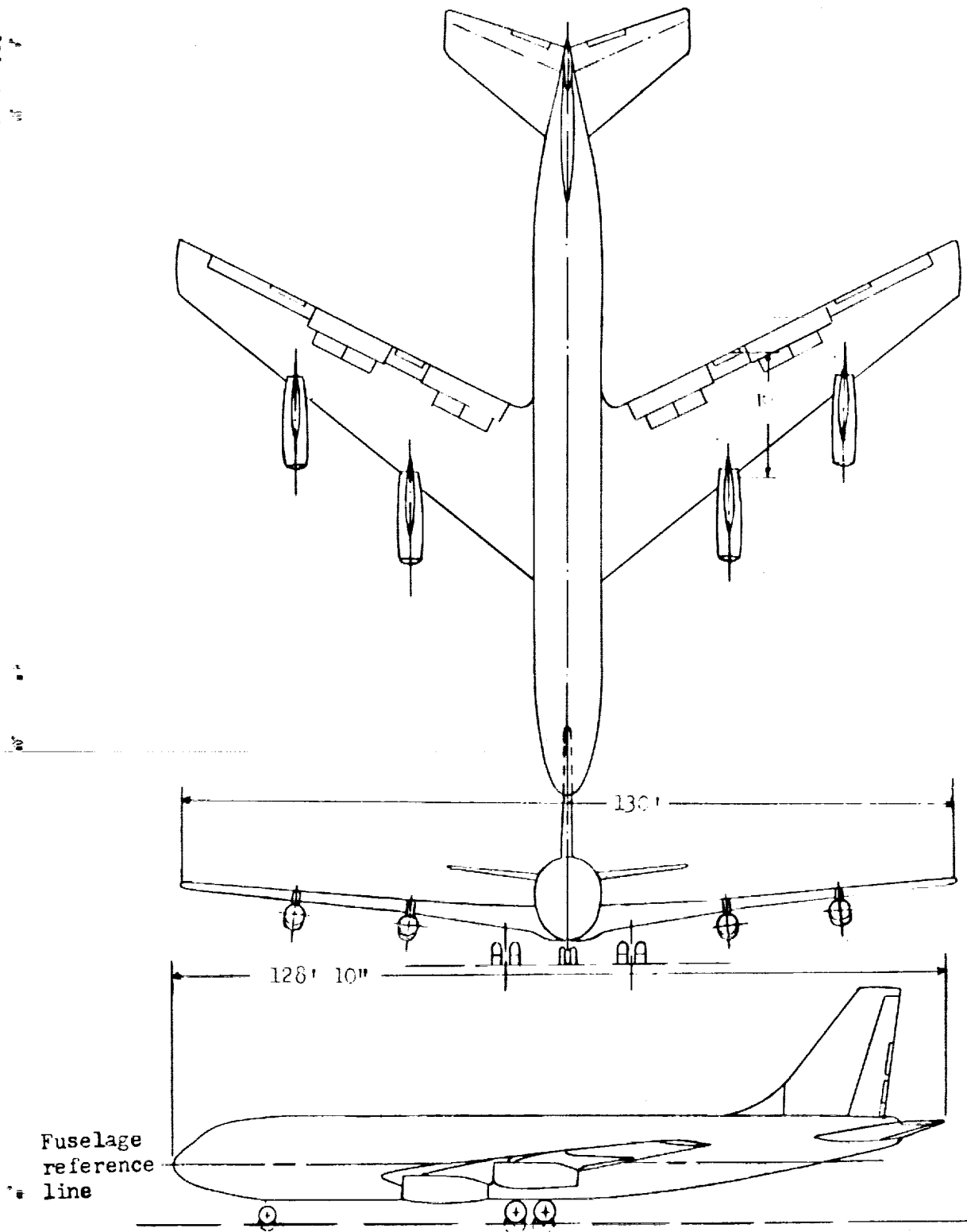
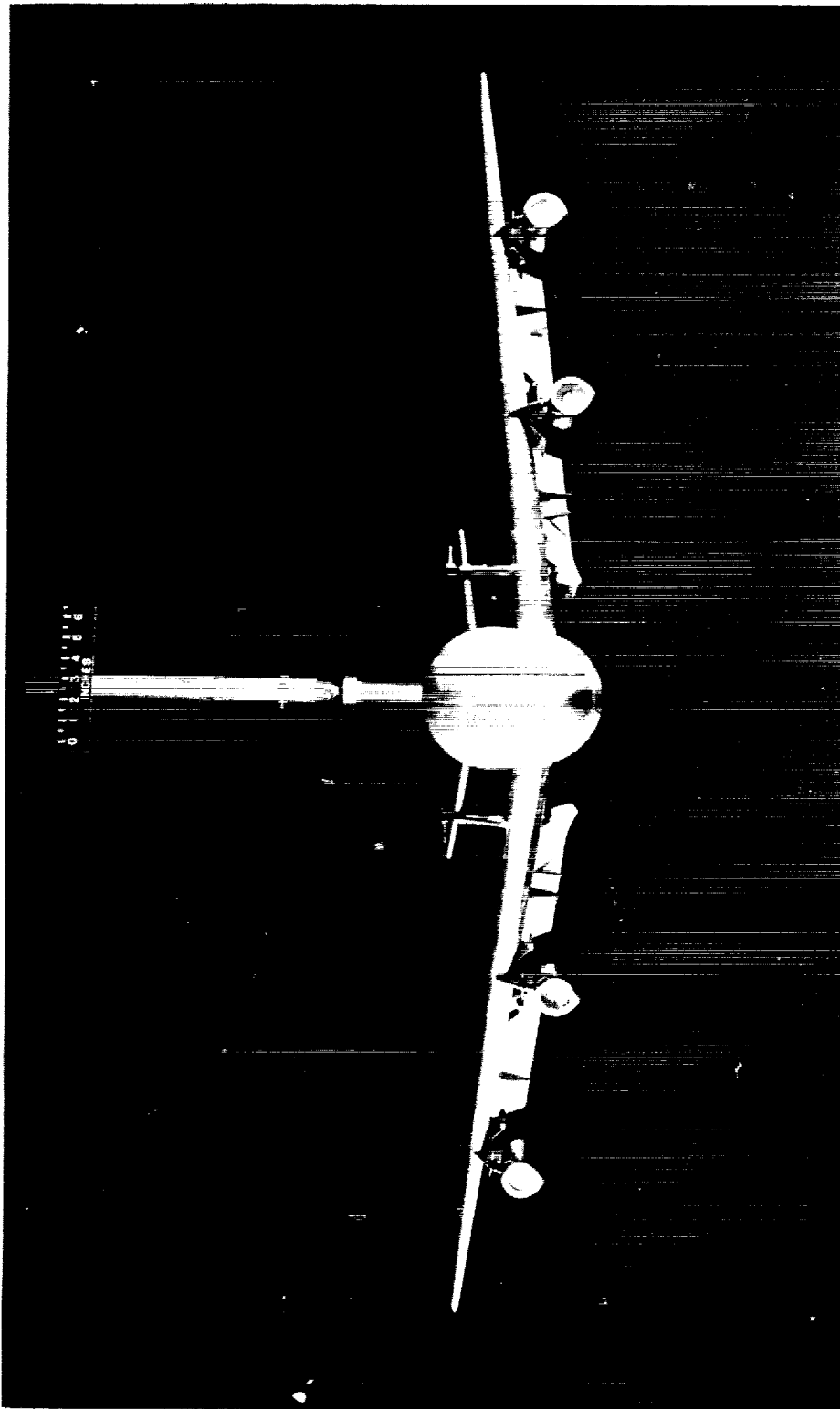
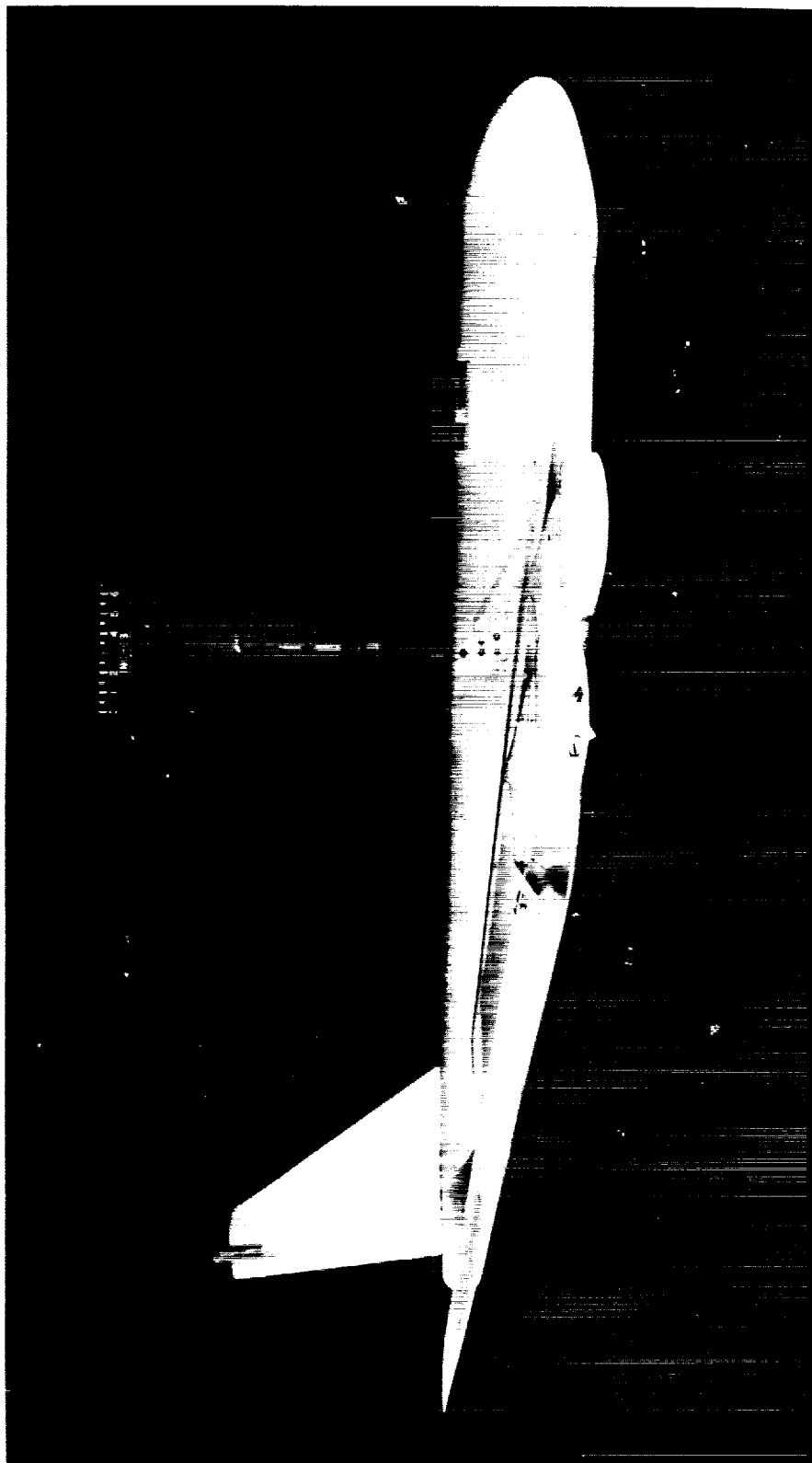


Figure 1.- Three-view drawing of the Boeing 707 jet transport.



L-85060
(a) Front view.

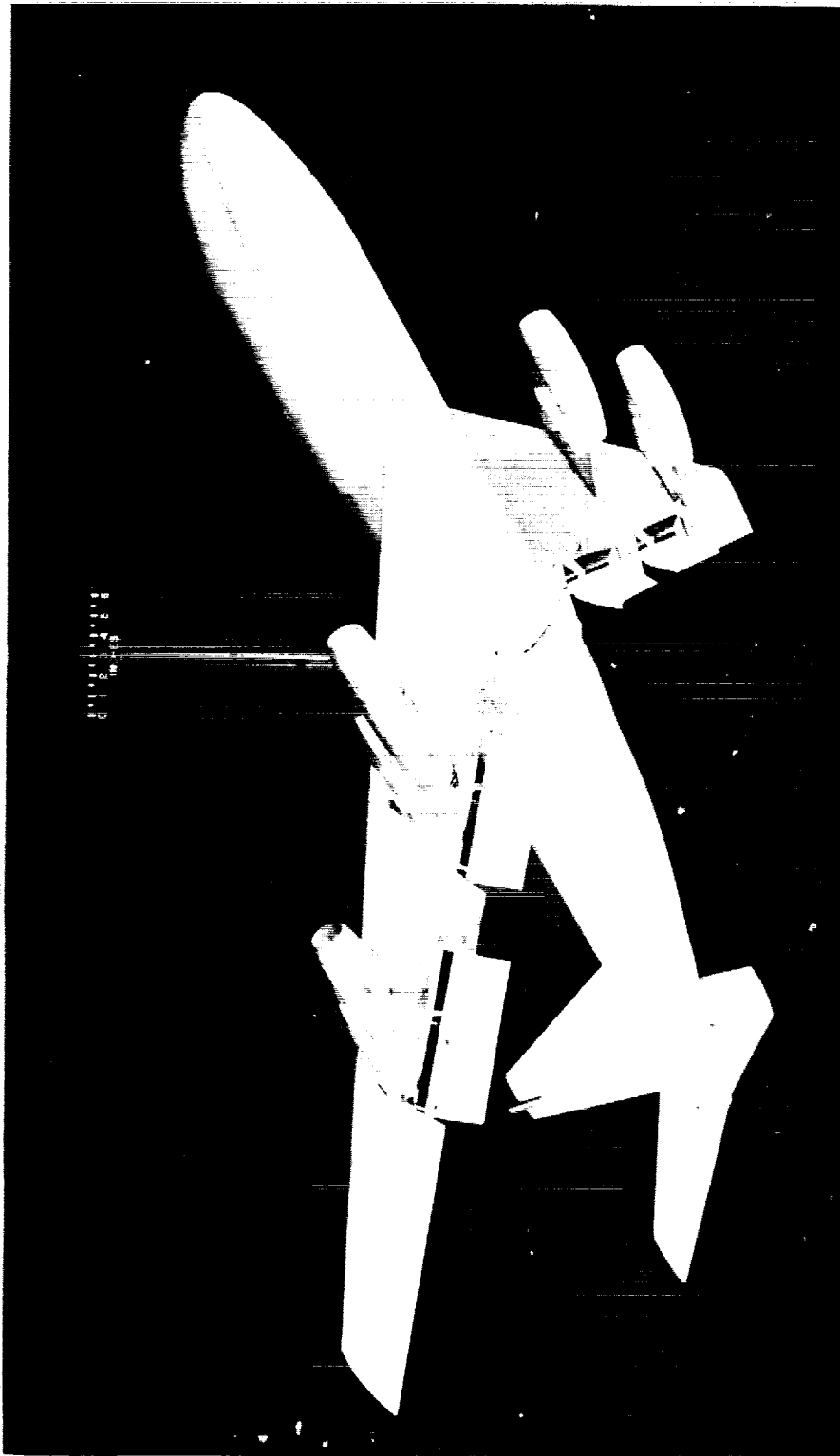
Figure 2.- The Boeing 707 jet transport ditching model.



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(b) Side view.

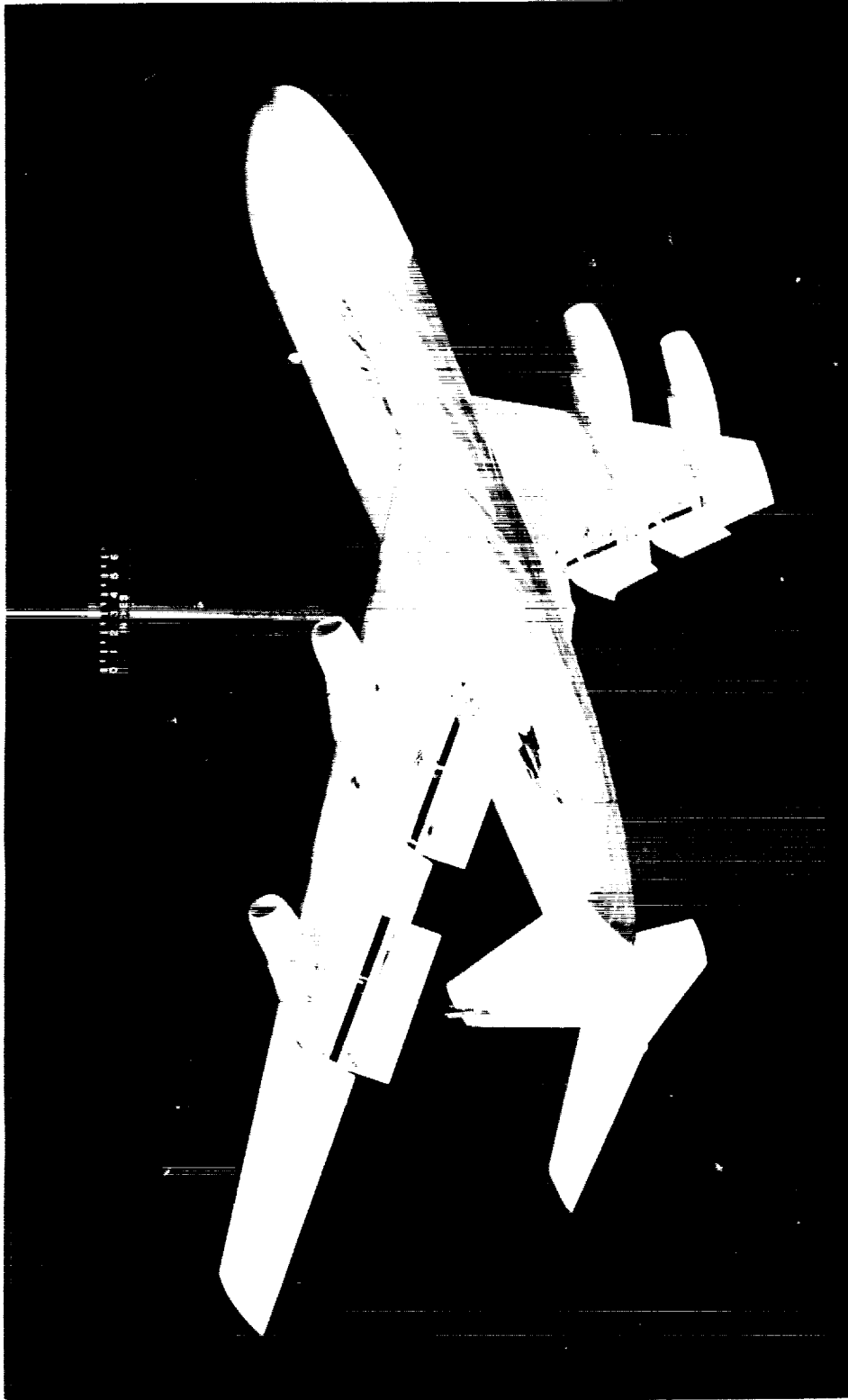
Figure 2.- Continued.



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(c) Three-quarter bottom view.

Figure 2.- Concluded.



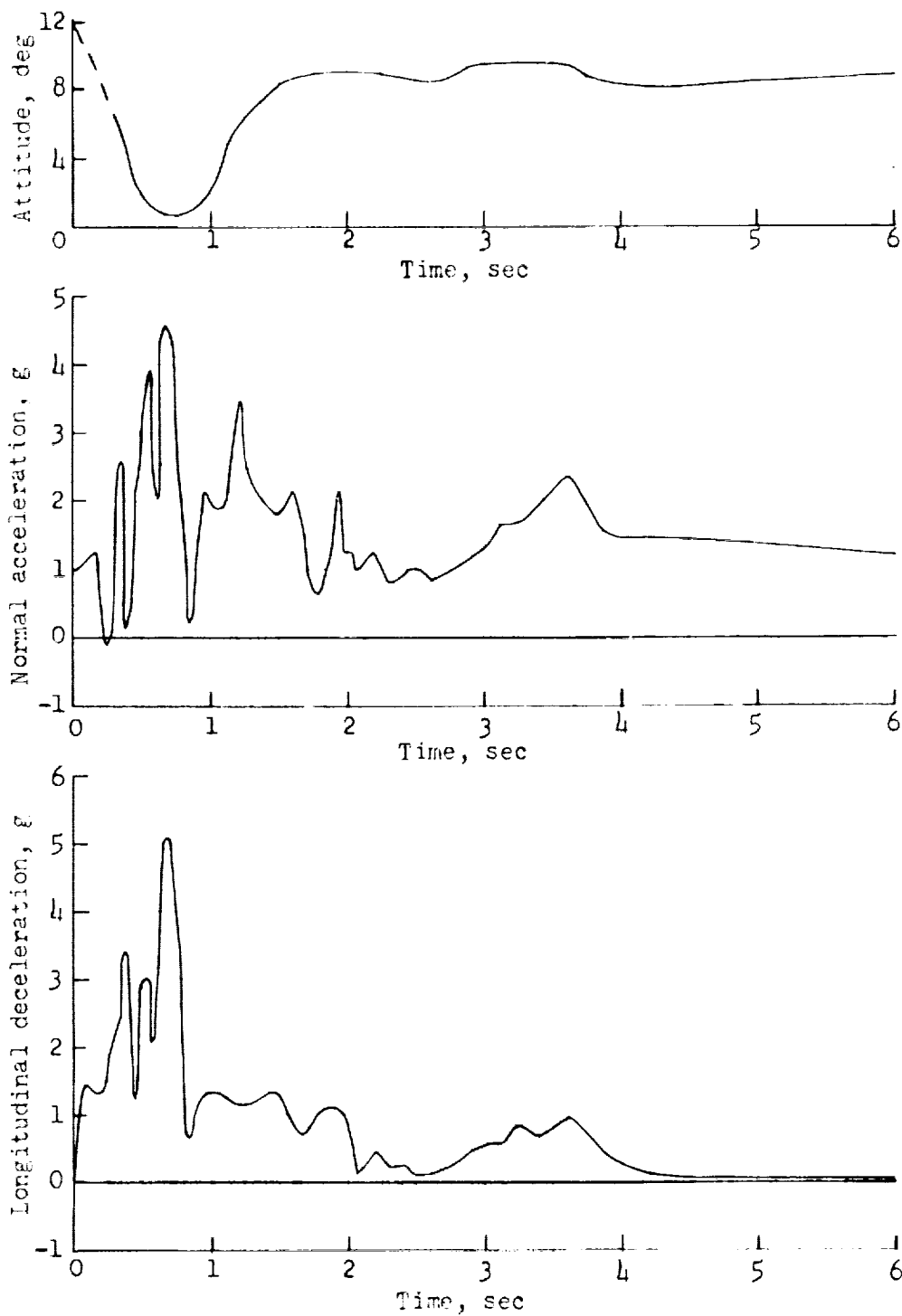
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Figure 3.- Model with scale-strength fuselage bottom section.



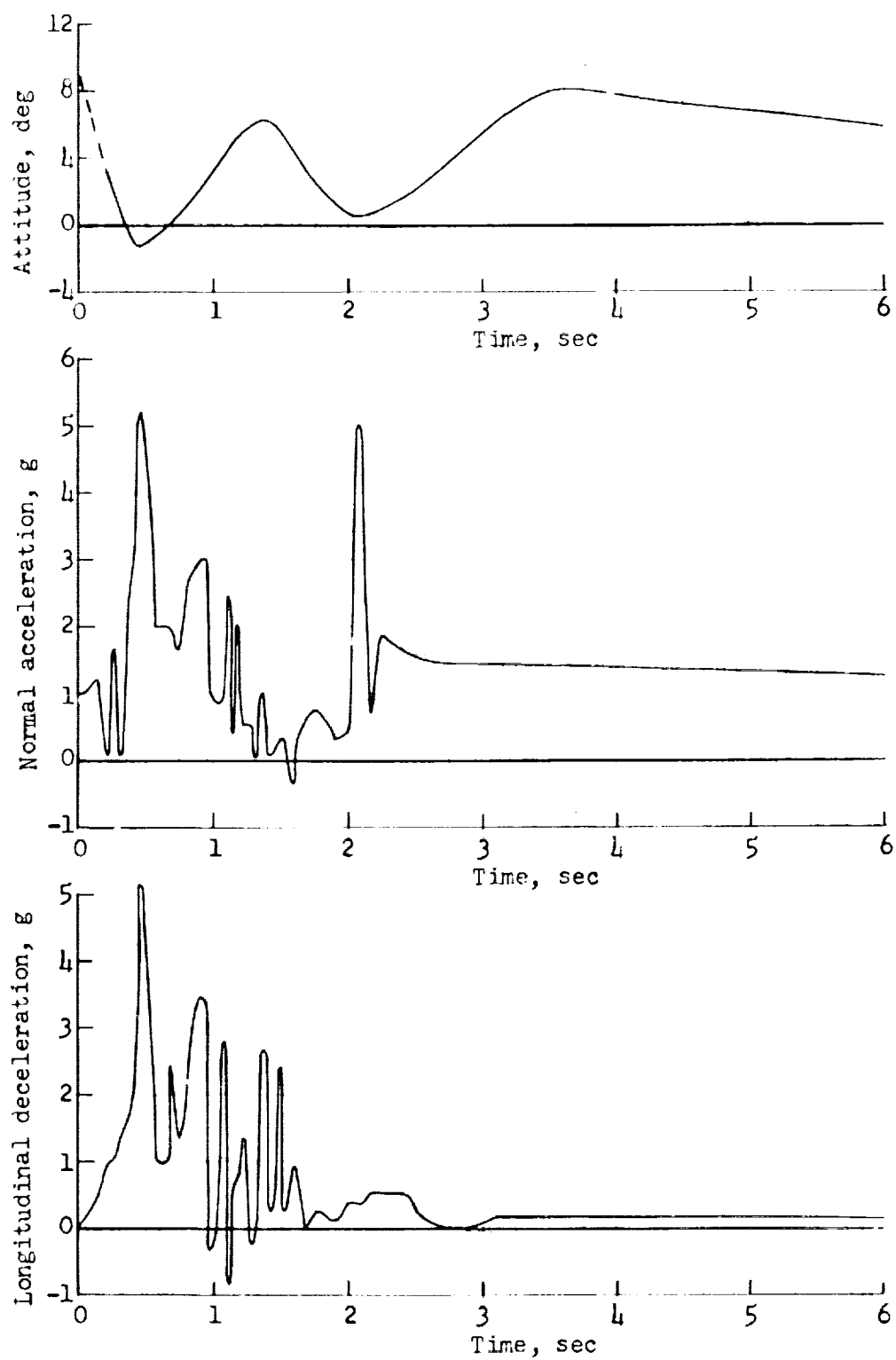
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Figure 4.- The Langley tank no. 2 monorail with a model attached.



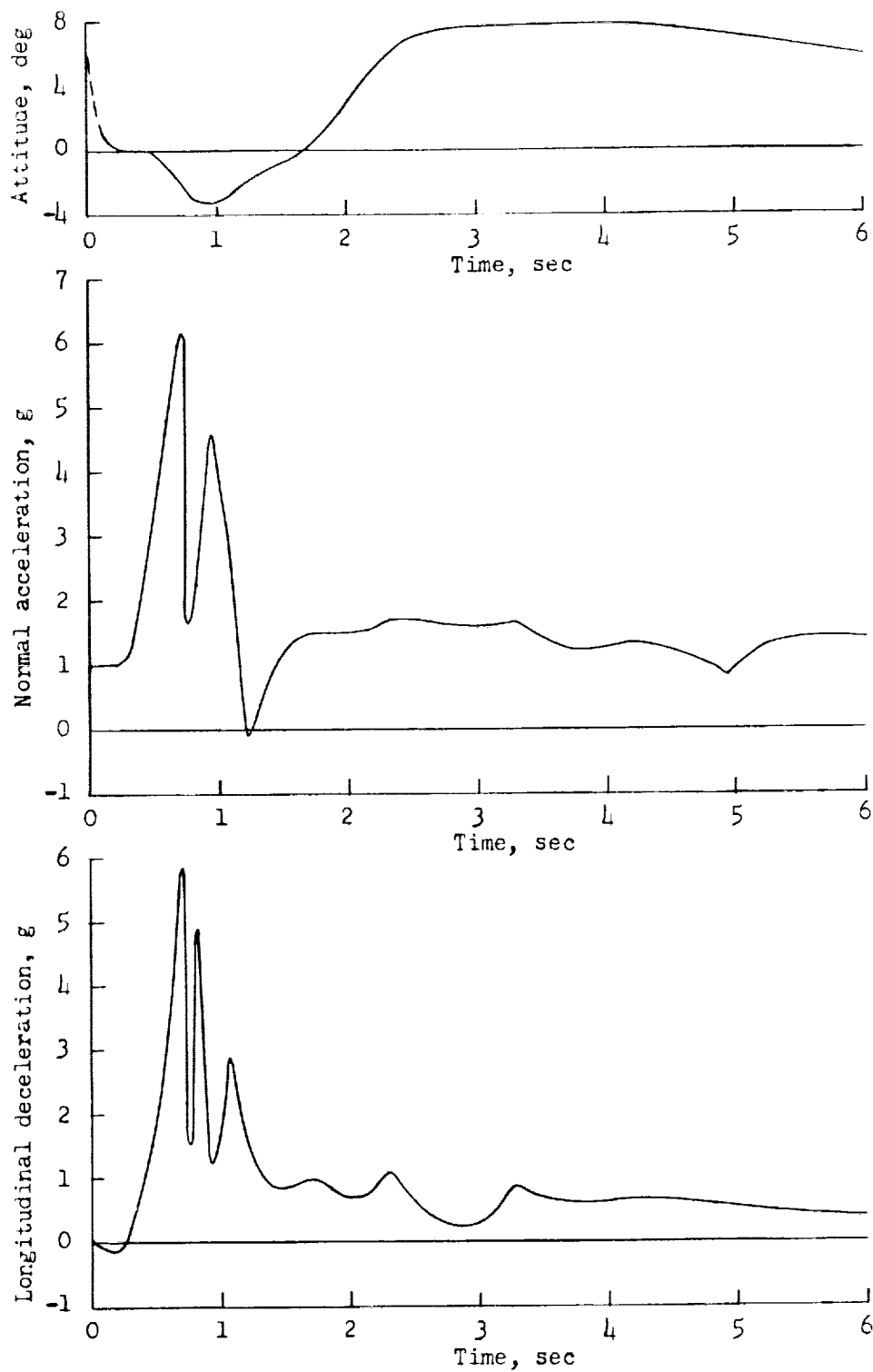
(a) Landing attitude, 12° ; landing speed, 100 knots.

Figure 5.- Time history of attitude and normal and longitudinal accelerations with scale-strength fuselage bottom and scale-strength nacelle struts installed. Flaps down; values are full-scale.



(b) Landing attitude, 9° ; landing speed, 10^4 knots.

Figure 5.- Continued.



(c) Landing attitude, 6° ; landing speed, 113 knots.

Figure 5.- Concluded.



Near contact



180 feet

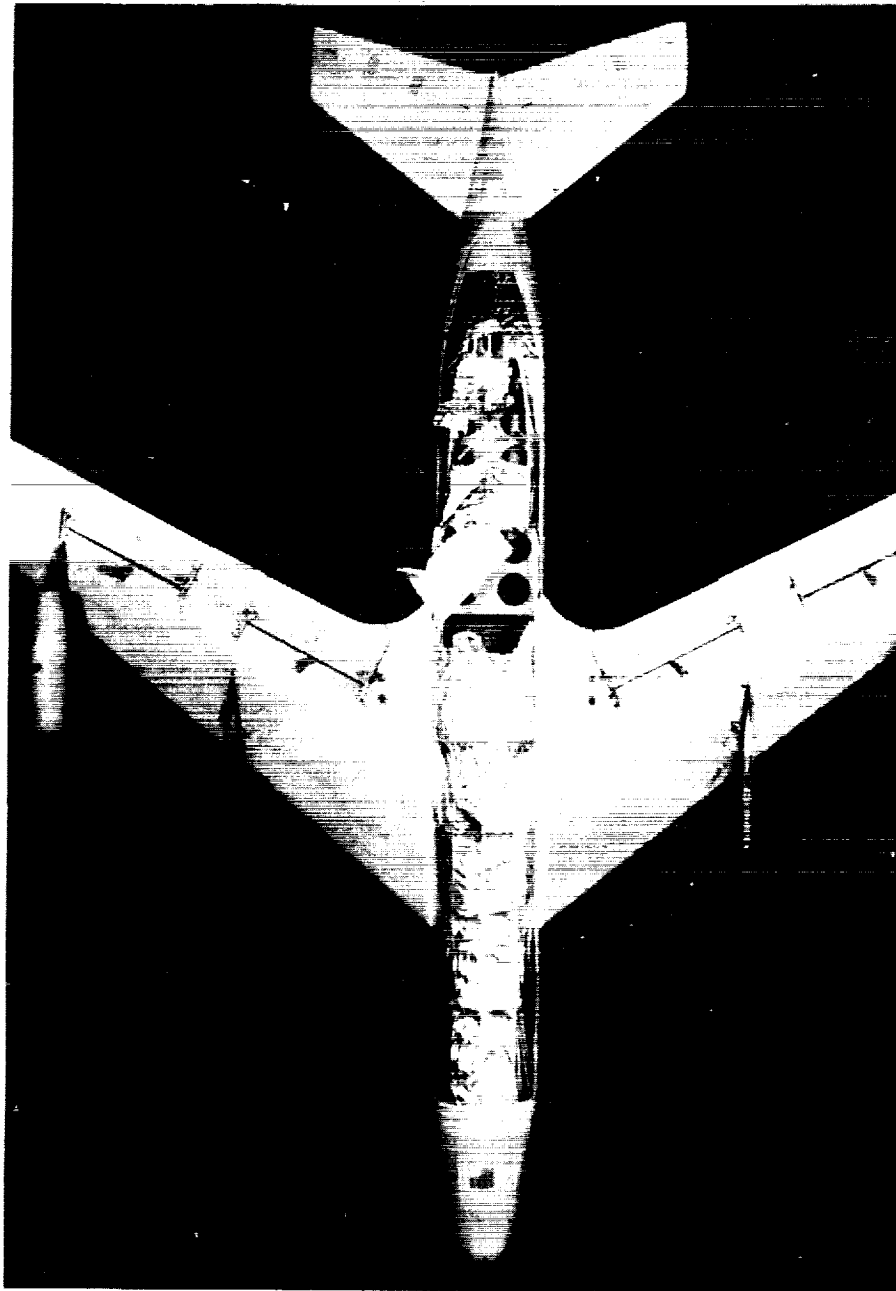


350 feet



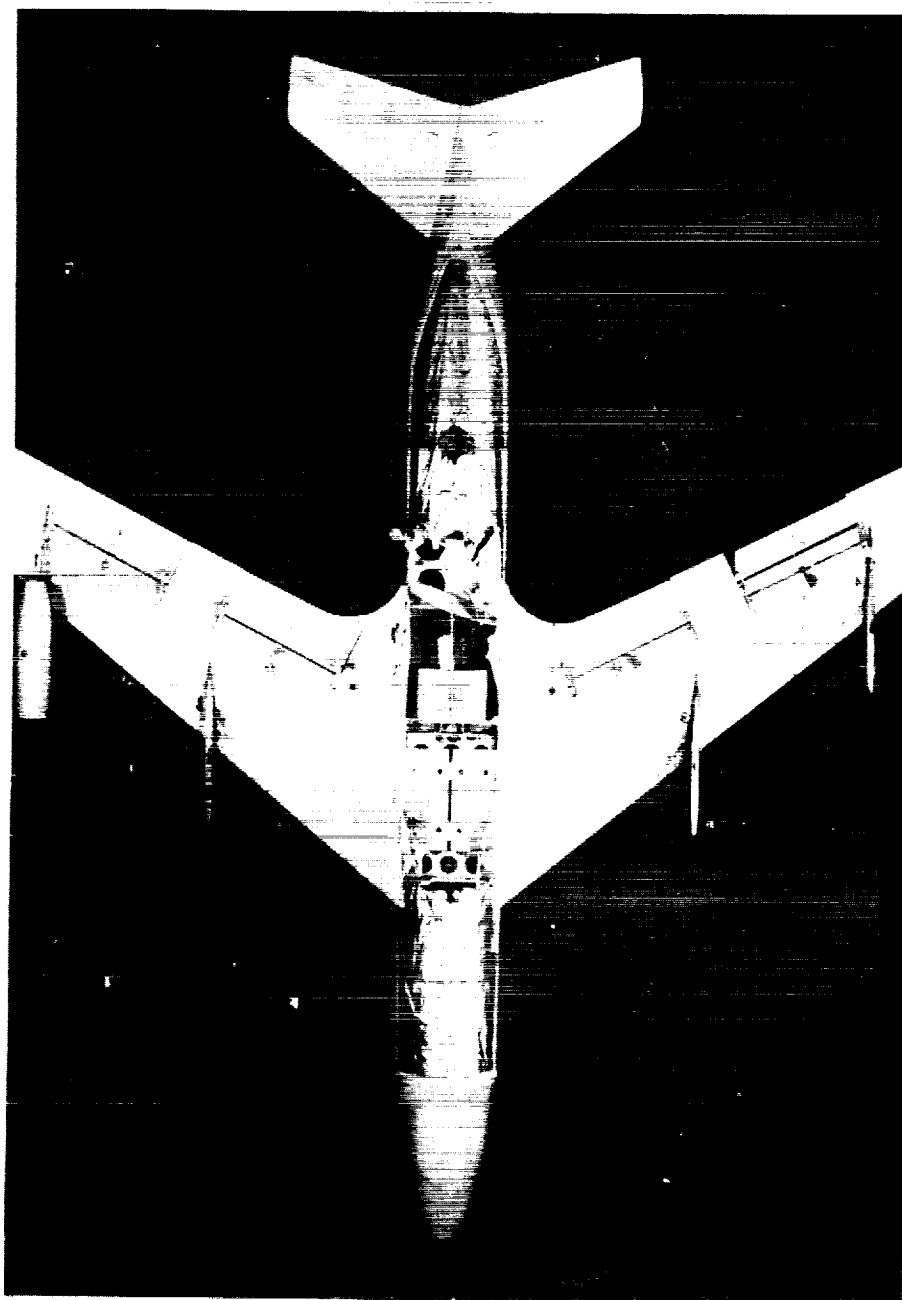
470 feet

Figure 6.- Sequence photographs of typical landing runs with scale-strength fuselage bottom and scale-strength nacelle struts installed. Flaps down; landing attitude, 12° ; landing speed, 100 knots. Distance after contact is indicated in feet. All values are full-scale.



(a) Landing attitude, 12° ; landing speed, 100 knots. L-90559

Figure 7.- Typical damage to the scale-strength bottoms. Flaps down.



(c) Landing attitude, 6° ; landing speed, 113 knots. L-90561

Figure 7.- Concluded.